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Original Article

ADAPTATION STRATEGIES FOR MITIGATION OF CLIMATE CHANGE IN WHEAT CROP (*TRITICUM AESTIVUM* L.) FOR GUJARAT

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ABSTRACT

The various alteration methods in agriculture to minimize the impact of climate change, viz. sifting sowing dates from a current, change in cultivar, remove water stress with an optimum dose of fertilizer and combine all above three, were tried using the model. The climate projection data for 2071-2100 obtained from PRECIS (Providing Regional Climate for Impact Study) model output was down the scale for different districts of Gujarat. The daily data were derived for rabi season and was used in the Crop simulation model (InfoCrop-wheat) to study. The study indicated that the maximum temperature is expected to rise by 3.2 to 5.2 ºC and the mean minimum temperature is expected to rise by 2.8 to 5.8 ºC in different study districts of Gujarat. The mean grain yield reduction due to the impact of climate change ranged from 33.8 percent in 30th November sowing to 45.8 percent under 15th December sowing in different districts.

The adverse effect of climate change can minimize by different adaptation strategies. Various adaptation methods can mitigate the negative impact of climate change on wheat crop up to 20.1 in different districts of Gujarat. The highest (-31.9%) vulnerable district for climate change on wheat yield was Banaskantha, and the lowest (-18.3 %) was in Junagadh.

KEYWORDS: Adaptation; InfoCrop; Wheat Crop & Gujarat

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INTRODUCTION

Gujarat ranks six in total wheat production of India with an area of 15.88 lakh hectares, about 50.13 lakh tones grains with average productivity of 3.15 t/ha as against 3.11 t/ha productivity of the nation (Anon., 2015). The productivity of Gujarat is equal to the national average but lower than Punjab, Haryana and Uttar Pradesh because the short winter season does not provide congenial for growth. Moreover, farmers are not aware of some agronomic practices for adaptation to this situation. The mean productivity of wheat in different districts of Gujarat varied between 1983.9 and 4014.9 kg/ha with a mean of 3001 kg/ha. The highest wheat yield was recorded as 4014 kg/ha at Junagadh, followed by Rajkot (3968.1 kg/ha) and Amreli (3664.5 kg/ha) district, whereas the lowest yield was recorded as 1983.9 kg/ha at Bharuch district. The average district productivity showed an increasing trend in all significant wheat-growing districts of Gujarat.

Different reports determinedly expected that by 2100 Earth's mean temperature will rise 1.4 to 5.8 ºC. In the Indian subcontinent, the temperature will increase 1.5 to 5 ºC and A_2 scenarios are specifically characterized due to population rise and locally sloping economic development along with the slowest technical improvement. CO_2 concentration is also found increasing trend under the projected period (2071 to 2100) and it is likely to reach from 626.2 in 2071 to 836.0 ppm in 2100 (IPCC, 2013). The higher concentration of CO_2 can be benefited by some of the C_3 crops like rice, wheat, etc. Chattopadhyay and Hulme (2007). The precipitation will decrease in subtropical

areas and increase in coastal regions of India, frequency of extreme events will increase significantly. The temperature is projected to grow more in the areas which are warmer at the current. The rise in the temperature is relatively more minor in the hilly regions. Precipitation during *Kharif* is projected to increase significantly in the north and north-east parts of the study region, while no perceptible change is projected for the western and southern parts comprising Upper Gangetic Plain Zone. (Aggarwal *et al*., 2010)

To maintain farming production under risk of expected climate change diverse adaptation procedures such as changes in land use and management, expansion of resources conserving technologies, natural resources managing policies, enhanced hazard executive through early structure and crop insurance, changing season/sowing windows, modification in irrigation/fertilizer management are to be addressed.

MATERIALS AND METHODS

The study was conducted with the wide objectives of simulation of four wheat cultivars and four different dates of sowing. The model was calibrated and validated with field experiment was conducted from during 2008-09 to 2011-12 at BACA, AAU, Anand, using following varieties and sowing dates. Four varieties are GW 322, GW 496, GW 366 and GW 1139 and sowing dates are D_1=1st November, D_2=15th November, D_3=30th November, D_4=15th December). Well calibrated and validated InfoCrop-wheat used for climate change impact and adaptation on wheat crop.

For climate change projection studies, PRECIS regional climate model was used. The PRECIS-derived data downscaled to 0.4-degree grid-scale (latitude) was obtained from IITM Pune since there is a difference between PRECIS-derived baseline daily weather data and actual weather data for the same period.

Impact Assessment Study

The validated InfoCrop model was used to simulation the phenology and the yield of wheat in different districts of Gujarat, namely Ahmedabad, Anand, Banaskantha, Bhavnagar, Dahod, Junagadh, Rajkot and Sabarkantha districts using for baseline (1961-90) and projected climate change under the A_2 scenario (2071-2100).

Adaptation and Vulnerability Analysis

The simulation was done to find the impact of different adaptation strategies like (1) Shifting sowing window (delay 15 days sowing date on a place of normal sowing date 15th November), (2) Change in variety (change variety GW 322 on the place of GW 496), (3) improved fertilizer (20% additional fertilizer and split into doses on the place of the recommended dose and split into two doses) and (4) irrigation management (two additional irrigation on the place of every phenological stage), and (5) combination on all strategies. A combination of these was put into the model and ran for climate change scenarios to identify alternate suitable adaptation combinations. For the study of the benefit of adaptation strategies, the cultivar GW 496 was used because it is the most popular cultivar in Gujarat and the normal sowing date 15th November was used as a base yield. Vulnerability = Impact (negative) – Adaptation (positive). In instances where impacts are positive, simulations were run for similar adaptation strategies for quantifying the additional benefits, and thus, net vulnerability values in these situations represent net positive impacts maximized with additional adaptation measures.

RESULT AND DISCUSSION

Calibration and validation of InfoCrop-Wheat Model

The paired test results between simulated and observed grain yield values were found to have been non-significant. The

averaged errors as computed by MAE, RMSE and PE were 199.1 kg/ha, 215.2 kg/ha and 6.0 percent respectively during validation periods. The calibrated InfoCrop-wheat model performed well for simulating phenological stages with an acceptable range of error percent so that the model can be used for impact assessment study.

Projected Mean Maximum Temperature

The results showed that the mean maximum temperature during the baseline period ranged between 32.1 ºC (Dahod) to 34.4 ºC in Ahmedabad district, while during the projected period, the maximum temperature ranged between 36.5 ºC (Junagadh) to 38.8 ºC (Bananskantha) (Table 1). The PRECIS outputs for the A2- scenarios (2071-2100) indicated that the mean maximum temperature is expected to rise by 3.2 to 5.2 ºC in different study districts. The lowest increase being in Junagadh district and the highest being in Banaskantha district. Aggarwal *et al.* (2010) also reported a rise in temperature under the Indo- Gangetic Plain Zone of Uttar Pradesh.

Projected Mean Minimum Temperature

The annual mean minimum temperature as projected by the PRECIS model for the period 2071-2100 in different districts of Gujarat, along with baseline data, are presented in Table 2

The results showed that the mean minimum temperature during the baseline period (1961-1990) ranged from 19.8 ºC (Anand) district to 22.1ºC (Banaskantha) district while the projected mean temperature under A2 scenario ranged between 23.1 ºC (Junagadh) district to 27.9 ºC (Bananskantha). The result indicated that the mean minimum temperature is expected to rise by 2.8 to 5.8 ºC in a different district. The highest increase in minimum temperature (5.8ºC) is projected in Banaskantha district and the lowest growth (2.8 ºC) is projected in Junagadh district at different districts of Gujarat. Similar results are reported by Kumar *et al.* (2010)

Projected Rainfall

The annual rainfall projected by PRECIS model along with the baseline period for different districts of Gujarat is presented in table 3.

The results indicated that the mean annual rainfall during the baseline period (1961-90) ranged between 455 to 919.2 mm the highest was in Anand district while the lowest was in Banaskantha district. The projected mean annual rainfall ranged between 671.6 mm in Banaskantha district to 1456.4 mm in Junagadh district. The projected climate indicated that the mean yearly precipitation would increase by 28 to 74 percent in different districts of Gujarat. The lowest increase rainfall in Ahmedabad and highest rainfall projected in Junagadh district. These results are in close agreement with the findings of Zhanga and Nearing (2005) who predicted a marked increase in the severe rainfall activities and rainfall increased over an extensive area covering the Western Ghats region of India.

Impact Assessment of Climate Change

The mean grain yield reduction due to the impact of climate change ranged from 33.8 percent in 30th November sowing to 45.8 percent under 15th December sowing in different districts. Among the varieties, the highest grain yield reduction due to climate change was under cv. GW 1139 in all sections of Gujarat and lowest in cv. GW 322. The highest yield was reduced to be projected in Banaskantha district and the lowest in Junagadh district. (fig 1)

Adaptation Strategies for Wheat to Climate Change

The adverse effect of climate change can minimize by different adaptation strategies presented in Tables 4 to 6.

Results depicted that the yield gain by shifting the sowing time by 15 days delay from the normal sowing the wheat yield is found increase by 4.3 to 9.9 percent in different districts. The highest benefit (9.9) was observed in the Dahod district, while the lowest (4.3) was in the Rajkot district. Although the shifting of showing window by 15 days had a beneficial effect (6.6) on wheat yield, it alone cannot compensate the loss due to climate change, while yielding gained by a change in variety in place of GW 496 variety GW 322 in all study districts. The yield gain by this adaptation strategy ranged between 4.1 percent at Bhavnagar to 11.1 percent at Banaskantha district. It is seen that the beneficial effect of the changing variety was more pronounced in Saurashtra region than in the eastern districts of Gujarat. Thus the changing the variety alone can make farmers better equipped to face the climate change impacts on wheat crops. It might be due to GW 322 is a temperature tolerant variety as compared to GW 496 and yield gain by 20 percent additional fertilizer projected to be up to 9.6 percent and the two extra irrigation gave nearly 10.0 percent higher yield over recommended quantity under projected period.

The model simulated output shows that the combination of all four adaptation strategies gave the highest benefit up to 20.1 percent in different districts. The highest benefitted district was Dahod (20.1%) and the lowest (8.2%) was Sabarkantha district. The average benefit of this adaptation was 16.2 in different districts. The combination of all strategies is more beneficial as compared to a single adaptation option.

The result shows that the highest (-31.9%) vulnerable district for climate change on wheat yield was Banaskantha district and lowest (-18.3 %) vulnerable district was Junagadh. Climate change with a net vulnerability after all adaptation strategies was found at Ahmedabad (-22.7), Anand (-25.8), Banaskantha (-31.9), Bhavnagar (28.4), Dahod (-19.1), Junagadh (-18.3), Rajkot (-28.3) and Sabarkantha (-26.8) percent.

CONCLUSIONS

Due to climate change, the duration of days to anthesis and maturity are projected to be reduced in all cultivars of wheat under all dates of sowing and in the entire district. The highest grain yield reduction due to climate change under cv.GW 1139 in and lowest in cv. GW 322 all districts. The mean grain yield reduction due to the impact of climate change ranged from 33.8 percent in 30th November sowing to 45.8 percent under 15th December sowing in different districts. The highest grain yield reduction due to climate change, projected in Banaskantha district and lowest in Junagadh districts of Gujarat. The adverse effect of climate change can minimize by different adaptation strategies. The yield gain by other adaptation methods is up to 20.1 percent in the projected period. The highest (-31.9%) vulnerable district for climate change on wheat yield was Banaskantha district and the lowest (-18.3 %) was Junagadh.

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Table 1: Projected Mean Maximum Temperature along with baseline Data in Different Districts of Gujarat

Districts	Baseline (1961-90) (ºC)	Projected (2071-2100) (ºC)	Difference (ºC)
Ahmedabad	34.4	38.5	4.1
Anand	33.2	37.8	4.6
Banaskantha	33.6	38.8	5.2
Bhavnagar	33.9	38.7	4.8
Dahod	32.1	36.6	4.5
Junagadh	33.3	36.5	3.2
Rajkot	33.7	37.5	3.8
Sabarkantha	34.2	38.3	4.1

Table 2: Projected Mean Minimum Temperature along with baseline Data in Different Districts of Gujarat

Districts	Baseline (1961-90) (ºC)	Projected (2071-2100) (ºC)	Difference (ºC)
Ahmedabad	21.2	24.7	3.5
Anand	19.8	24.1	4.3
Banaskantha	22.1	27.9	5.8
Bhavnagar	21.3	25.6	4.3
Dahod	20.7	24.5	3.8
Junagadh	20.3	23.1	2.8
Rajkot	20.1	23.5	3.4
Sabarkantha	21.7	26.2	4.5

Table 3: Percent Change in Annual Rainfall in Different Districts of Gujarat during Projected Period over baseline Rainfall

Districts	Baseline (1961-90) (mm)	Projected (2071-2100) (mm)	%Change
Ahmedabad	862.7	1105.6	28.0
Anand	919.2	1312.3	42.7
Banaskantha	455.2	671.6	47.5
Bhavnagar	627.2	967.5	54.2
Dahod	841.4	1432.1	70.2
Junagadh	836.2	1456.4	74.1
Rajkot	660.1	1076.2	63.0
Sabarkantha	692.1	906.5	30.9

Table 4: Simulated Wheat Yield with and without Adaptation (shifting sowing period) in Different Districts of Gujarat

Districts	Yield before Adaptation (kg/ha)	Yield after Adaptation (1) (kg/ha)	% Change
Ahmedabad	2957	3121	5.3
Anand	2650	2851	7.1
Banaskantha	2278	2431	6.3
Bhavnagar	2811	3120	9.7
Dahod	2726	3020	9.9
Junagadh	3217	3388	5.1
Rajkot	2678	2798	4.3
Sabarkantha	2715	2854	4.9
Mean	-	-	6.6

Adaptation strategy (1): Delay 15 days sowing date on place of normal sowing date 15th November.

Table 5: Simulated Wheat yield with and without Adaptation Strategy (Changing Variety) in Different Districts of Gujarat

Districts	Yield before Adaptation (kg/ha)	Yield after Adaptation (2) (kg/ha)	% Change
Ahmedabad	2957	3245	8.9
Anand	2650	2841	6.7
Banaskantha	2278	2563	11.1
Bhavnagar	2811	2930	4.1
Dahod	2726	3011	9.5
Junagadh	3217	3451	6.8
Rajkot	2678	2941	9.0
Sabarkantha	2715	2966	8.5
Mean			8.1

Adaptation strategy (2): Improved variety (Change variety GW 322 on the place of GW 496)

Table 6: Simulated Wheat yield with and without Adaptation Strategy (Additional Fertilizer) in Different Districts of Gujarat

Districts	Yield before Adaptation (kg/ha)	Yield after Adaptation (3) (kg/ha)	% Change
Ahmedabad	2957	3255	9.2
Anand	2650	2948	10.1
Banaskantha	2278	2655	14.2
Bhavnagar	2811	3099	9.3
Dahod	2726	2854	4.5
Junagadh	3217	3512	8.4
Rajkot	2678	2971	9.9
Sabarkantha	2715	3072	11.6
Mean			9.6

Adaptation strategy (3): 20% additional fertilizer and split in doses on place of recommended dose and split in two doses.

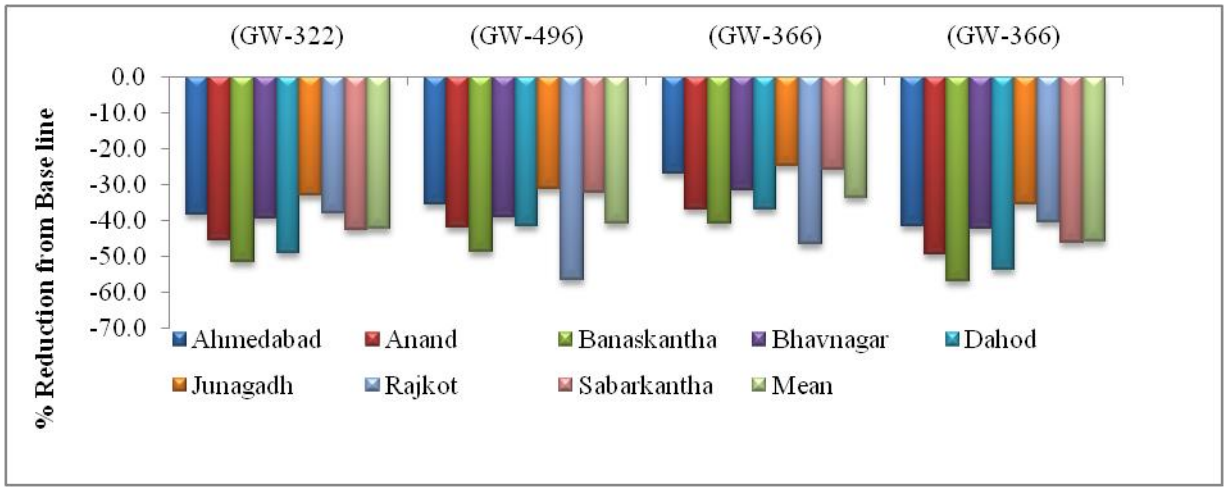

Figure1: Impact of Climate Change under A2 Scenario (2071-2100) as Compare to baseline (1961- 90) on Grain yield of Wheat in Different Cultivars at Various Districts of Gujarat.